DØ Program at LBNL

Director’s Review of Physics Division
November 8, 2000

Thomas G. Trippe

- LBNL D0 Group
- Run 1 Physics Analyses
- D0 Upgrade
- Physics Studies
- Silicon Responsibilities
- Visual Alignment
- Electron/Photon ID
- Level 3 Tracking, Trigger
- SVX2E Readout Chip
- Other Responsibilities
- Conclusions

The DØ Collaboration

U. of Arizona
U. of California, Berkeley
U. of California, Davis
U. of California, Irvine
U. of California, Riverside
Cal State U., Fresno
Lawrence Berkeley Nat. Lab.
Florida State U.
Fermilab
U. of Illinois, Chicago
Northern Illinois U.
Northwestern U.
Indiana U.
U. of Notre Dame
Iowa State U.
U. of Kansas
Kansas State U.
Louisiana Tech U.
U. of Maryland
Boston U.
Northeastern U.
U. of Michigan
Michigan State U.
U. of Nebraska
Columbia U.
U. of Rochester
SUNY, Stony Brook
Brookhaven Nat. Lab.
Langston U.
U. of Oklahoma
Brown U.
U. of Texas, Arlington
Texas A&M U.
Rice U.
U. of Washington

U. de Buenos Aires

LAFEX, CBPF, Rio de Janeiro
State U. do Rio de Janeiro
State U. Paulista, São Paulo

IHEP, Beijing

U. de los Andes, Bogotá

Charles U., Prague
Czech Tech. U., Prague
Academy of Sciences, Prague

U. San Francisco de Quito

ISN, IN2P3, Grenoble
CPPM, IN2P3, Marseille
LAL, IN2P3, Orsay
LPNHE, IN2P3, Paris
DAPNIA/SPP, CEA, Saclay
IPN, IN2P3, Villeurbanne

IOP, U. Mainz
Ludwig-Maximilians U, Munich

Panjab U., Chandigarh
Delhi U., Delhi
Tata Institute, Mumbai

KDL, Korea U., Seoul

CINVESTAV, Mexico City

FOM-NIKHEF, Amsterdam
U. of Amsterdam/NIKHEF
U. of Nijmegen/NIKHEF

INP, Kraków

JINR, Dubna
ITEP, Moscow
Moscow State U.
IHEP, Protvino
PNPI, St Petersburg

Lund U.
RIT, Stockholm
Stockholm U.
Uppsala U.

Lancaster U.
Imperial College, London
U. of Manchester

LBNL D0 Group Personnel

LBNL Staff

Emanuela Barberis*
Al Clark**
Frederic Fleuret* (French visitor)
Charles Leggett* (also NERSC)
Ron Madaras
Mark Strovink
Tom Trippe (also PDG)

Graduate Students

Bruce Knuteson (at FNAL since 5/98)
Daniel Whiteson (at FNAL since 5/00)

Undergraduate Students

(Patrick Pfleiderer)

* Postdoc
** Retiree

D0 Run 1 Physics Analyses with LBNL Principal Authorship

Topic	Physics Goal	Status
Top Quark Physics:		
m_t in ℓ+jets events	Use novel cuts to increase S/N, with high eff, which don't bias top mass spectrum.	**PRL 79, 1197 (1997)** **PR D 58, 52001 (1998)**
m_t in $\ell\ell$ events	Independent m_t measurement.	**PRL 80, 2063 (1998)** **PR D 60, 52001 (1999)**
CDF/D0 m_t average	FNAL m_t average, include correlations.	**Fermilab-TM-2084 (99)**
Jet energy scale	Reduce systematic error on m_t (also for jet inclusive cross section...)	**NIM 424, 352 (1999)**
Electroweak Physics:		
$\sigma_W B$, $\sigma_Z B$, $\Gamma(W)$	QCD test, SM test of W decay modes.	**PRL 75, 1456 (1995)** **PR D 60, 52003 (1999)**
$W\gamma$ production	Measure $WW\gamma$ gauge boson couplings.	**PRL 75, 1034 (1995)** **PR D 56, 6742 (1997)**
WW,WZ production	Measure $WW\gamma$ and WWZ couplings.	**PRL 77, 3303 (1996)**
$P_T(W)$ spectrum	Test pQCD & soft gluon resummation.	**PRL 80, 5498 (1998)**
New Particle Searches:		
Search for W_R & W'	W_R search for large range of $M(N_R)$.	**PRL 76, 3271 (1996)**
Search in $e\mu X$ data	Search $e\mu X$ data for new physics with Sleuth	**PR D 62, 92004 (2000)**
General search	Search for new high P_T physics with Sleuth.	PRL & PRD in collab rev

Sleuth

A quasi-model-independent new physics search strategy

- A paradigm shift in the way that searches for new phenomena should be performed
- Emphasizes an *understanding of the data* (rather than what the data have to say about a particular model)
- Provides a systematic method for analyzing the *entire* data set (leave no stone unturned!)

A few of the many advantages of Sleuth

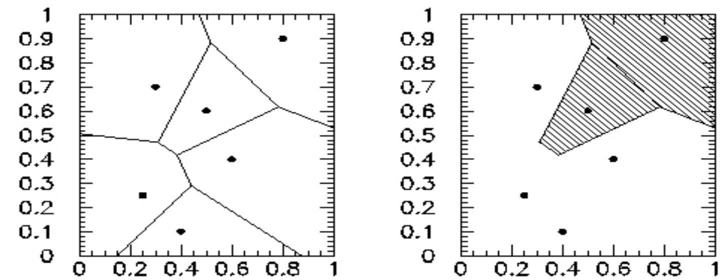
- Allows an approach that keeps attention focused on the most promising channels (rather than optimizing cuts for a signal that does not exist)
- Allows an *a posteriori* quantification of the "interestingness" of a few observed events.
- Intuitive and visual in nature (not a black box)
- Allows for surprises . . .

The Algorithm

- Define exclusive final states, and variables to consider for each
  - The variables (0 to 4 of them, depending on the final state) are object p_T's

Then for each final state . . .

Input: 1 data file, estimated backgrounds



- define regions about sets of data points
  - Voronoi diagrams
- define the "interestingness" of an arbitrary region
  - the probability that the background within that region fluctuates up to or beyond the observed number of events
- search the data to find the most interesting region, $\mathcal{R}$
- Determine $\mathcal{P}$, the fraction of *hypothetical similar experiments* (hse's) in which you would see something more interesting than $\mathcal{R}$
  - Take account of the fact that we have looked in many different places

Output: $\mathcal{R}$, $\mathcal{P}$

Results

$e\mu X$: $t\bar{t}$ sensitivity check & new physics result

Let the backgrounds include

1)
- fakes
- $Z \to \tau\tau$
- WW
- tt

2)
- fakes
- $Z \to \tau\tau$
- WW
- tt

3)
- fakes
- $Z \to \tau\tau$
- WW
- $t\bar{t}$

DØ data

Data Set	$\mathcal{P}$
$e\mu\not{E}_T$	2.4σ
$e\mu\not{E}_T j$	0.4σ
$e\mu\not{E}_T jj$	2.3σ
$e\mu\not{E}_T jjj$	0.3σ
Combined	1.9σ

Excesses corresponding (presumably) to WW and $t\bar{t}$

DØ data

Data Set	$\mathcal{P}$
$e\mu\not{E}_T$	1.1σ
$e\mu\not{E}_T j$	0.1σ
$e\mu\not{E}_T jj$	1.9σ
$e\mu\not{E}_T jjj$	0.2σ
Combined	1.2σ

Excess corresponding (presumably) to $t\bar{t}$

DØ data

Data Set	$\mathcal{P}$
$e\mu\not{E}_T$	1.1σ
$e\mu\not{E}_T j$	0.1σ
$e\mu\not{E}_T jj$	0.5σ
$e\mu\not{E}_T jjj$	-0.5σ
Combined	-0.6σ

No evidence for new physics

Results

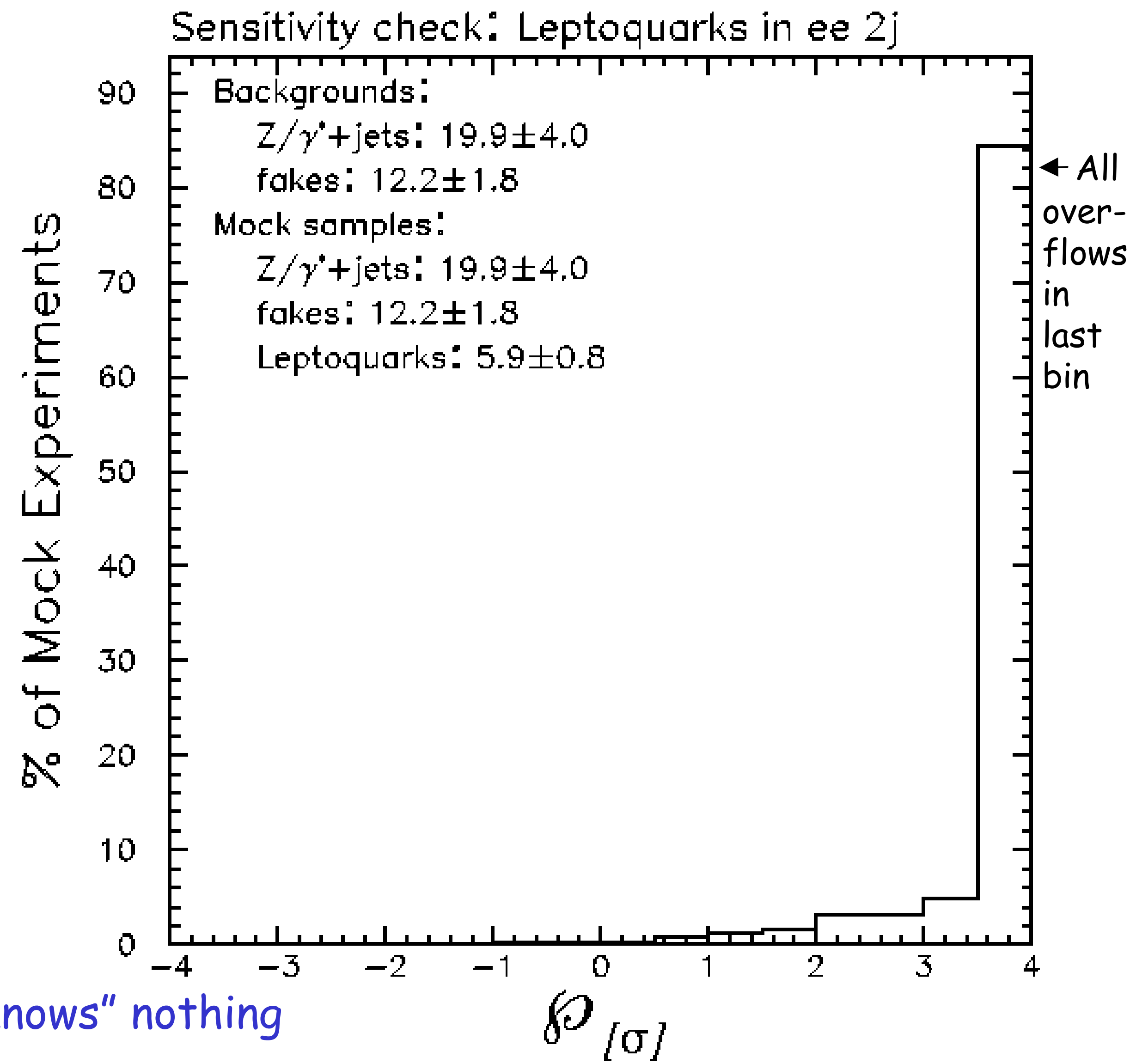
Sensitivity check: Leptoquarks in eejj

We can run mock experiments with hypothetical signals

What if our data contained leptoquarks?

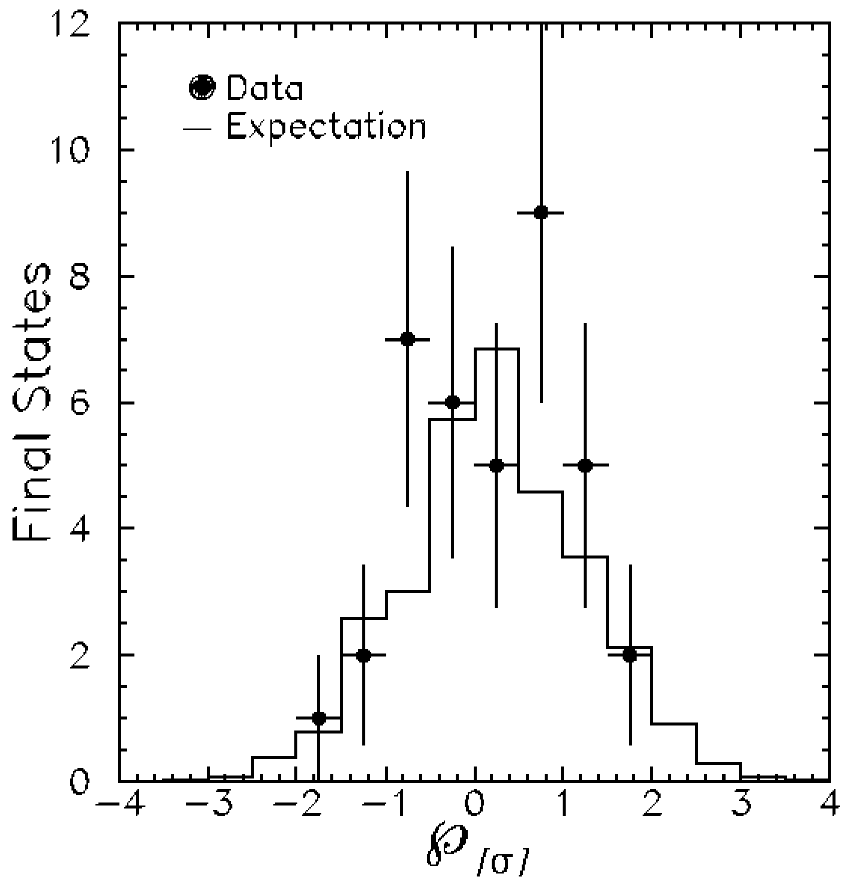
(Assume scalar, $\beta = 1$, $m_{LQ} = 170$ GeV)

Sleuth finds $\mathcal{P} > 3.5\sigma$ in > 80% of the mock experiments



(Remember that Sleuth "knows" nothing about leptoquarks!)

Results DØ data



Applied to ~half of 80 D0 final states

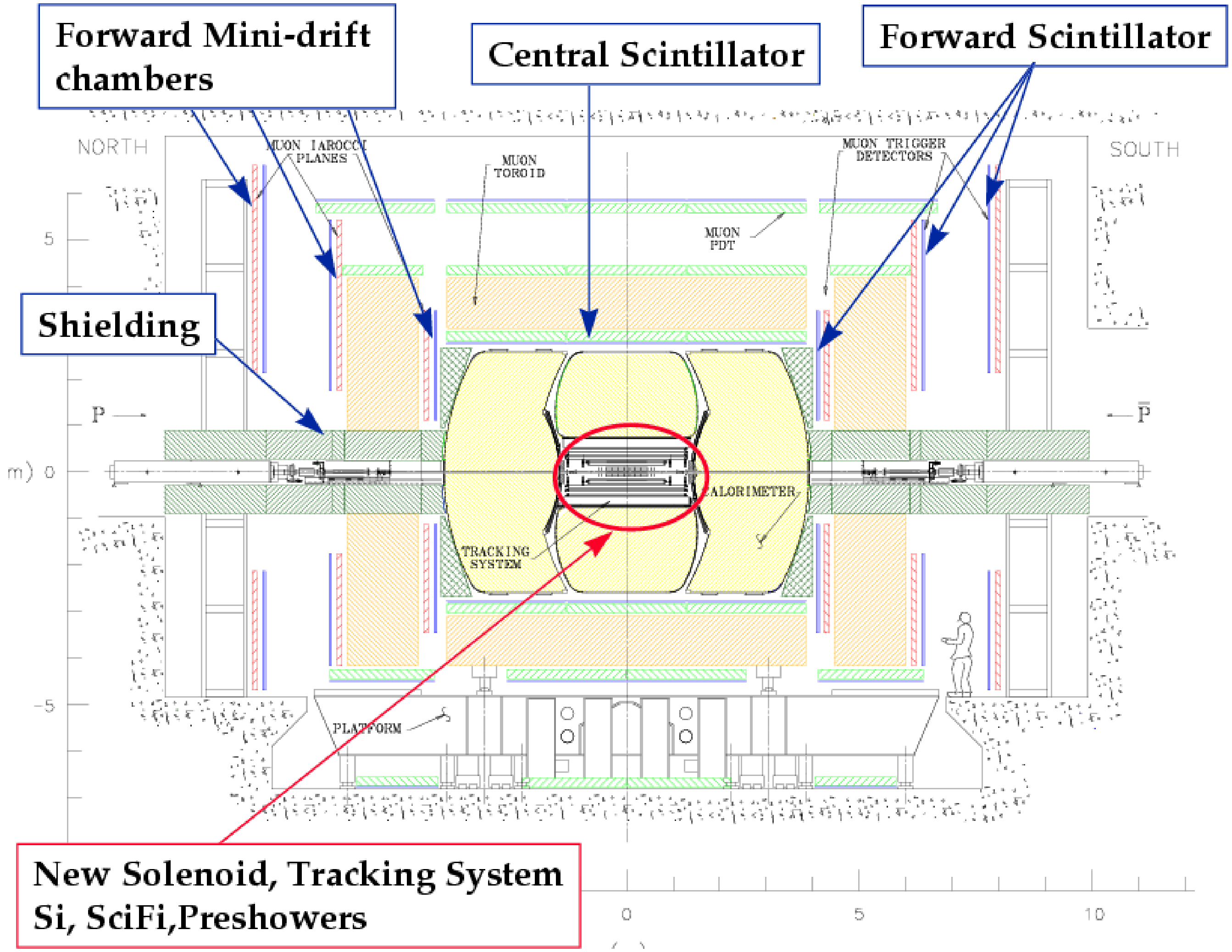
Results agree well with expectation

No evidence of new physics is observed

$$\tilde{\mathcal{P}} = 0.89$$

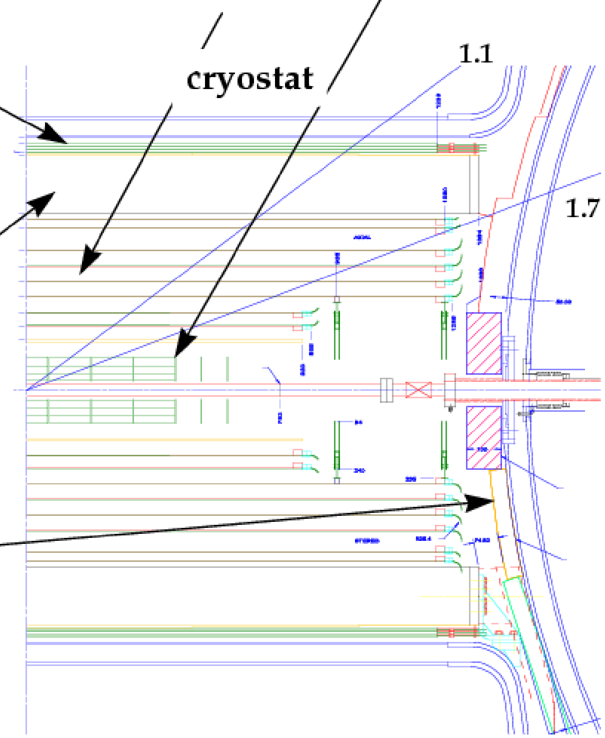
Data set	$\mathcal{P}$
$e\mu X$	
$e\mu \not\!\!E_T$	0.14 ($+1.08\sigma$)
$e\mu \not\!\!E_T j$	0.45 ($+0.13\sigma$)
$e\mu \not\!\!E_T\ 2j$	0.31 ($+0.50\sigma$)
$e\mu \not\!\!E_T\ 3j$	0.71 (-0.55σ)
W+jets-like	
$W\ 2j$	0.29 ($+0.55\sigma$)
$W\ 3j$	0.23 ($+0.74\sigma$)
$W\ 4j$	0.53 (-0.08σ)
$W\ 5j$	0.81 (-0.88σ)
$W\ 6j$	0.22 ($+0.77\sigma$)
$e \not\!\!E_T\ 2j$	0.76 (-0.71σ)
$e \not\!\!E_T\ 3j$	0.17 ($+0.95\sigma$)
$e \not\!\!E_T\ 4j$	0.13 ($+1.13\sigma$)
Z+jets-like	
$Z\ 2j$	0.52 (-0.05σ)
$Z\ 3j$	0.71 (-0.55σ)
$Z\ 4j$	0.83 (-0.95σ)
$ee\ 2j$	0.72 (-0.58σ)
$ee\ 3j$	0.61 (-0.28σ)
$ee\ 4j$	0.04 ($+1.75\sigma$)
$ee \not\!\!E_T\ 2j$	0.68 (-0.47σ)
$ee \not\!\!E_T\ 3j$	0.36 ($+0.36\sigma$)
$ee \not\!\!E_T\ 4j$	0.06 ($+1.55\sigma$)
$\mu\mu\ 2j$	0.08 ($+1.41\sigma$)
$(\ell/\gamma)(\ell/\gamma)(\ell/\gamma)X$	
eee	0.89 (-1.23σ)
$Z\gamma$	0.84 (-0.99σ)
$Z\gamma j$	0.63 (-0.33σ)
$ee\gamma$	0.88 (-1.17σ)
$ee\gamma \not\!\!E_T$	0.23 ($+0.74\sigma$)
$e\gamma\gamma$	0.66 (-0.41σ)
$e\gamma\gamma j$	0.21 ($+0.81\sigma$)
$e\gamma\gamma\ 2j$	0.30 ($+0.52\sigma$)
$W\gamma\gamma$	0.18 ($+0.92\sigma$)
$\gamma\gamma\gamma$	0.41 ($+0.23\sigma$)
$\tilde{\mathcal{P}}$	0.89 (-1.23σ)

D0 Detector Upgrade



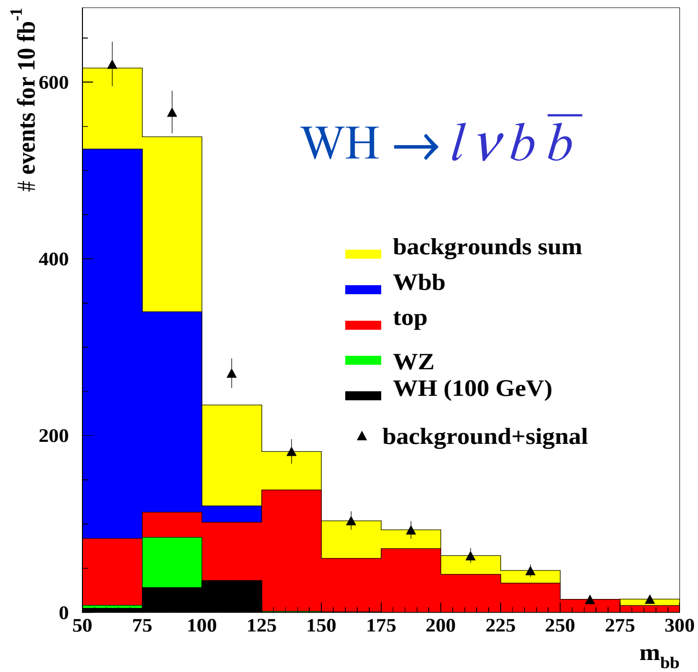
+ New Electronics, Trig, DAQ

- Silicon Tracker
  - Four layer barrels (double/single sided)
  - Interspersed double sided disks
  - 840,00 channels
- Fiber Tracker
  - Eight layers sci-fi ribbon doublets (z-u-v, or z)
  - 74,000 830um fibers w/ VLPC readout
- Central Preshower
  - Scintillator strips, WLS fiber readout
  - 6,000 channels
- Solenoid
  - 2T superconducting
- Forward Preshower
  - Scintillator strips, stereo, WLS readout
  - 16,000 channels

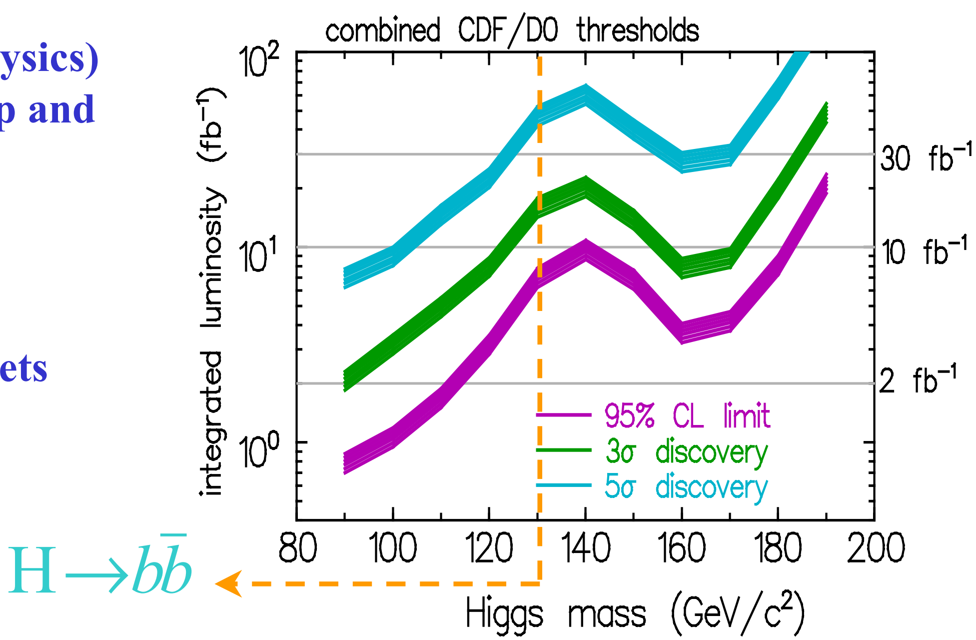


Higgs/Top Physics in RunII

- **Higgs RunII report final:**
  Report of the Higgs Working Group of the Tevatron Run 2 SUSY/Higgs Workshop, Fermilab-Conf-00/279-T, hep-ph/0010338, October 31, 2000.
  Contributed analysis of the WH→ $l\,\nu\,b\,\bar{b}$ channel @Tevatron, the most sensitive for light Higgs searches (favored by EW fits and LEP searches)

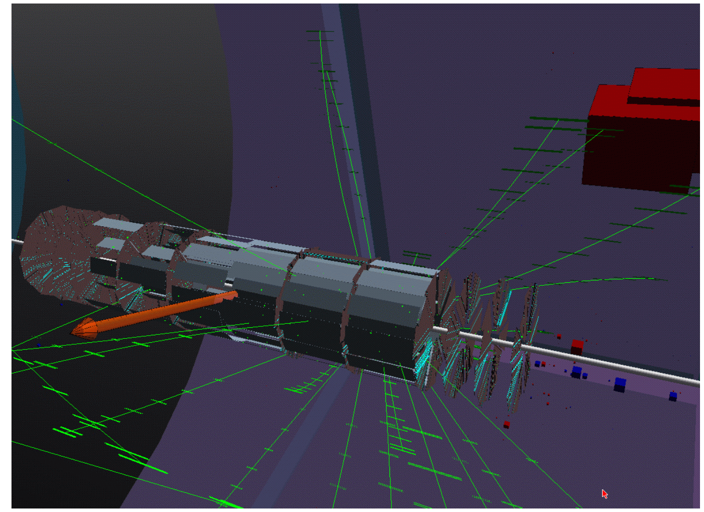


- **b-jet tagging studies:**
  (crucial for light Higgs searches and top physics) optimization of b-tagging algorithms for top and Higgs



- **Top RunII:**
  studies for precision measurement in the l+jets channel

Silicon Tracker Microstrip Offline Software



leadership and individual contribution to:

* geometry
* clustering, hit finding
* Monte Carlo modeling
* graphics display

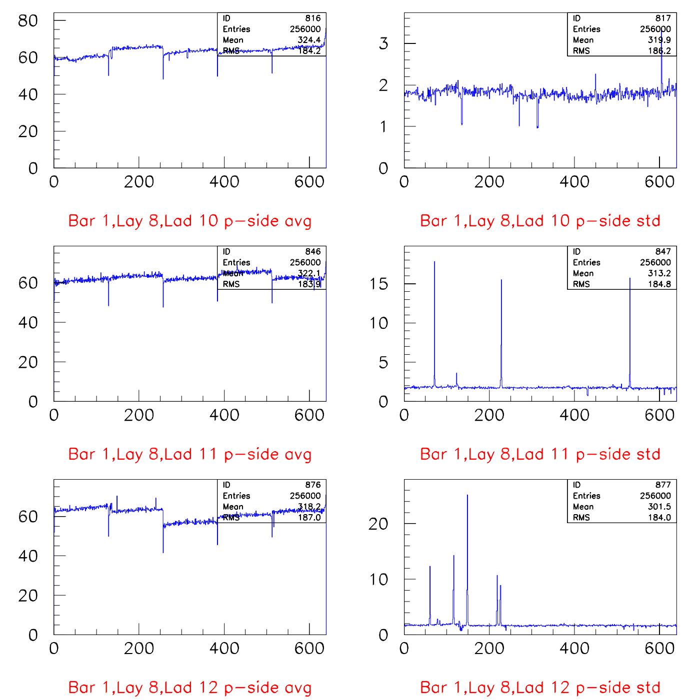
intensive testing w/ MC data, started to test+tune w/ data from full barrel&disk assemblies.

* calibration
* alignment
* graphical alignment
* online monitoring

- defined db tables (ORACLE)
- designed C++ access
- testing transfer of constants from online to offline db machine

- define strategies for disk alignment

- uses offline framework and the full DAQ chain
- monitoring of occupancies, pedestals and noise

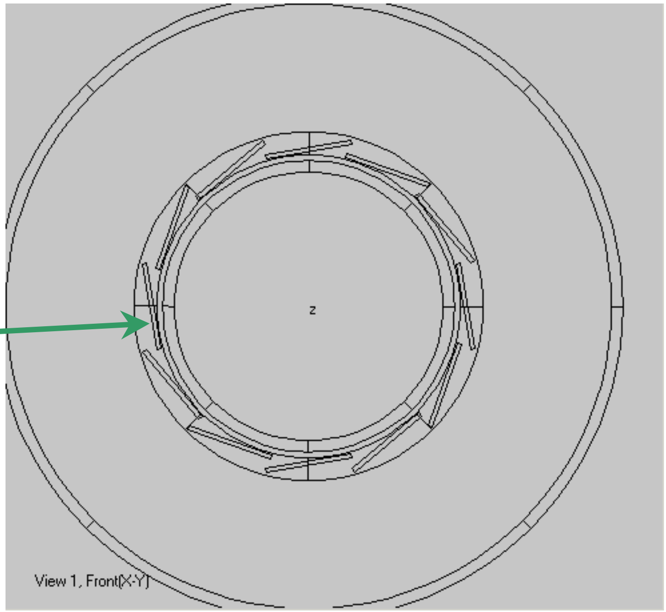


RunIIb Silicon upgrade studies

Silicon replacement after a delivered luminosity of 2-4fb^{-1} $\Rightarrow$ significant radiation damage to the inner 1-3 layers of the present Silicon Tracker

Layer0 Pixel (1.5 cm radius) option: high radiation tolerance, fine ($r\phi$,rz) segmentation with low occupancy

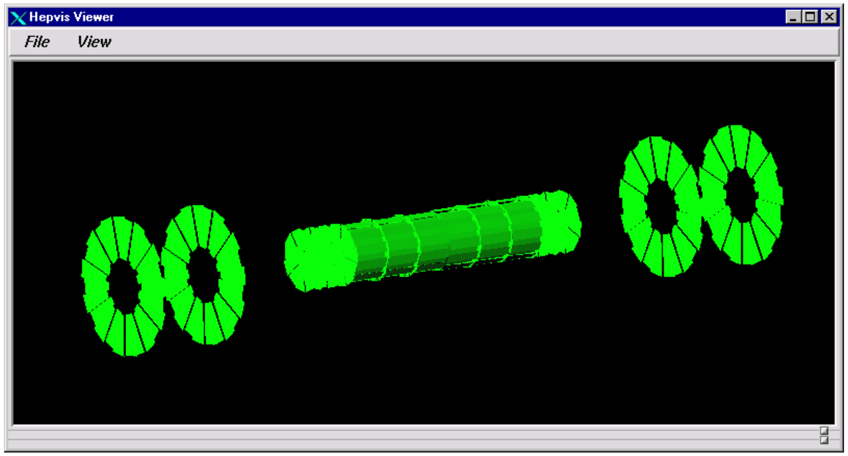
* feasibility studies
* impact on pattern recognition and on impact parameter resolution



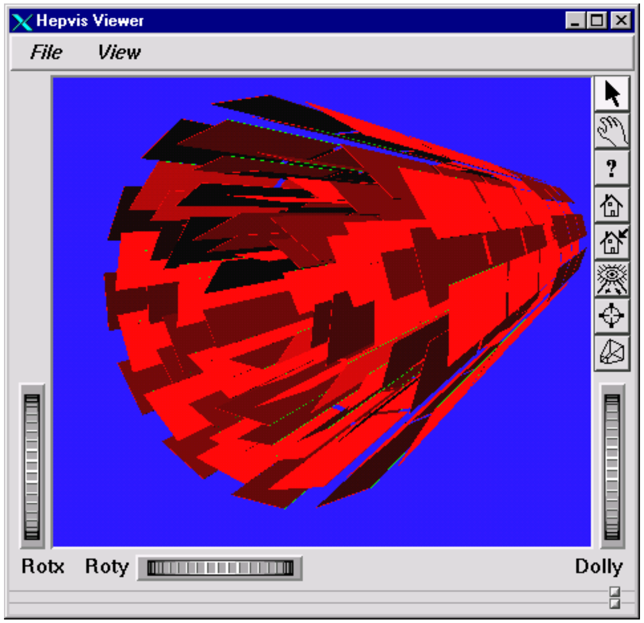
Visual Alignment

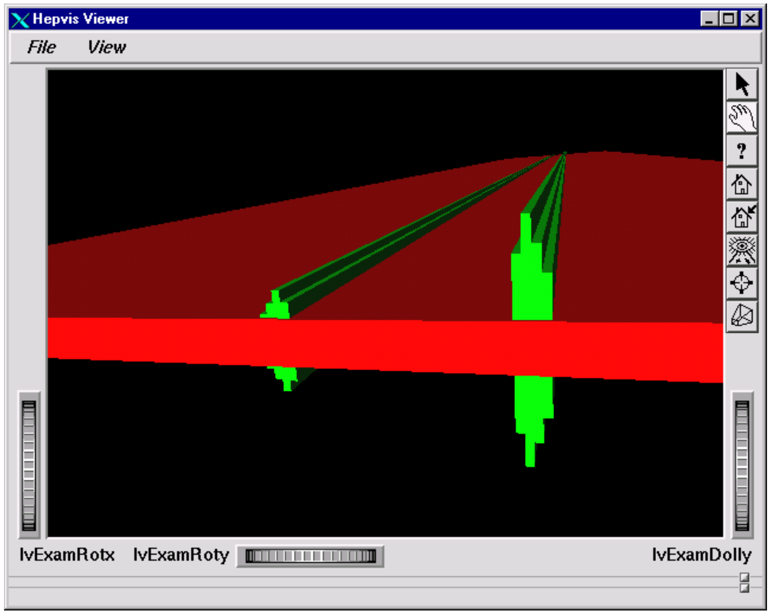
- Visual alignment method being developed
- Alignment info. represented as field of 3D residual vectors
- 3D residual vectors include location, direction, magnitude, and full covariance matrix
- Useful for visualization of alignment problems
- Useful for calculation of alignment parameters
- Displays of Silicon Microstrip Tracker were developed
- Developing common infrastructure for this and the standard D0 alignment program

Display of SMT geometry using Open Inventor

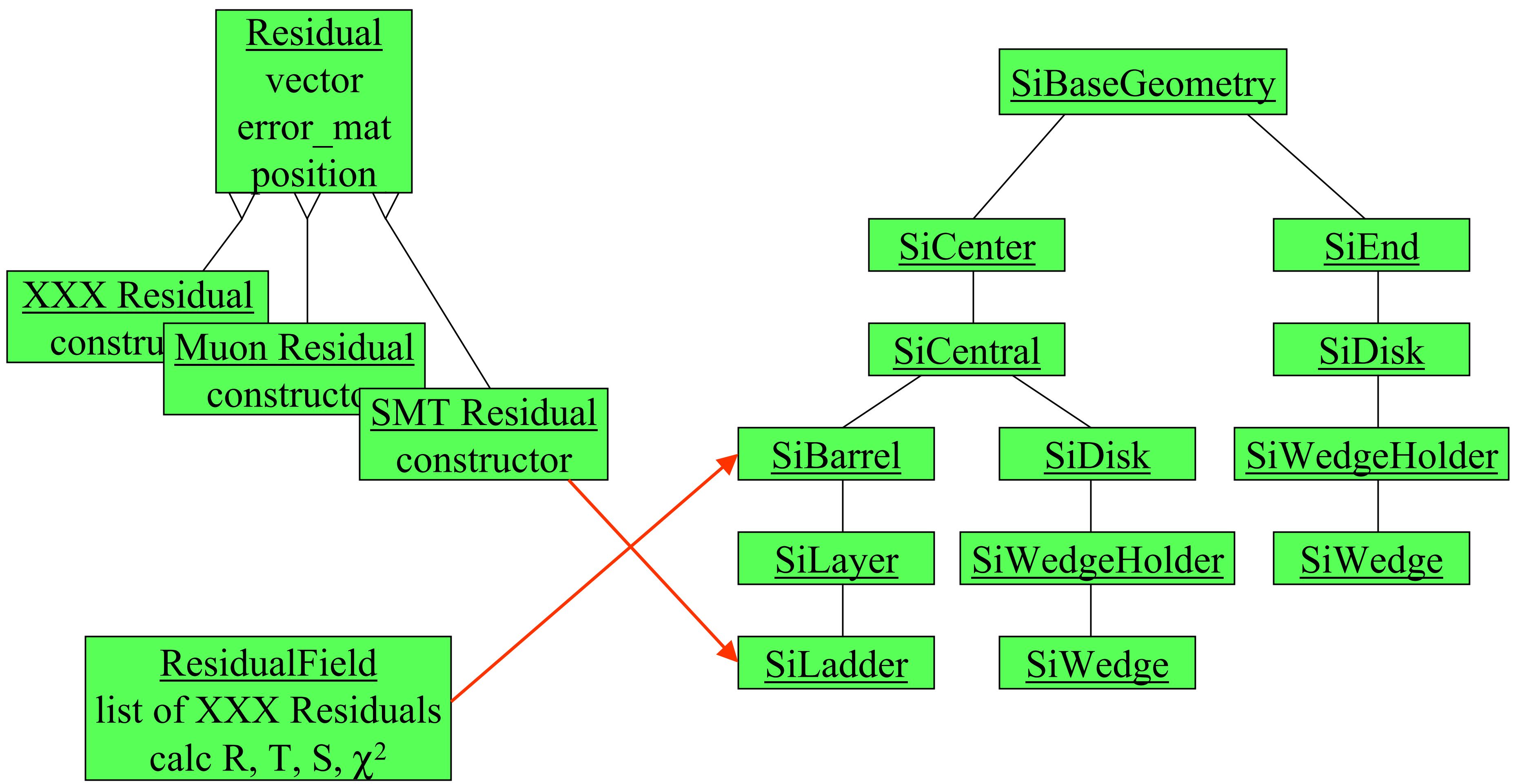


Detailed barrel display with ADC counts (Hepvis)





SMT Class Structures for Alignment



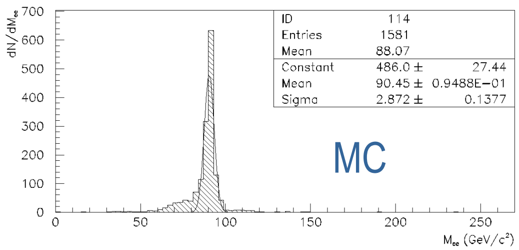
Electron and Photon ID Effort

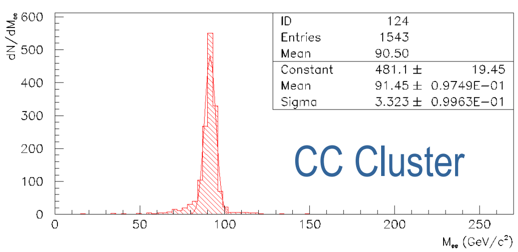
Example: M_{ee} for 2 highest p_T e's from Z→ee + 1 bkg evt

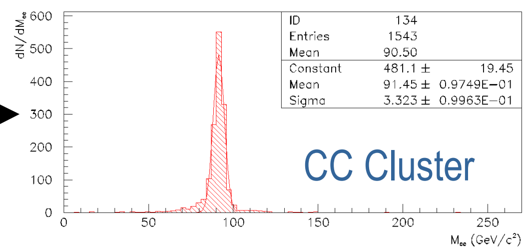
CC fiducial region

CPS fiducial region

TRK fiducial region
+ opposite sign

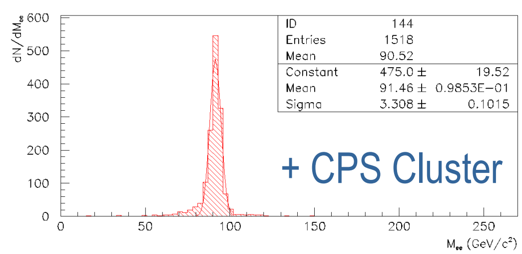


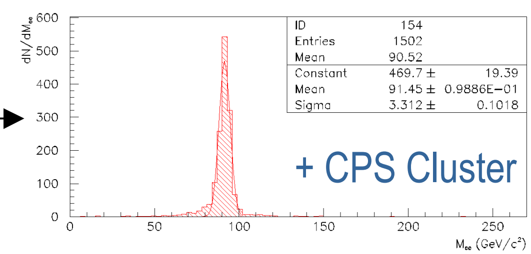




86% (93% per e)

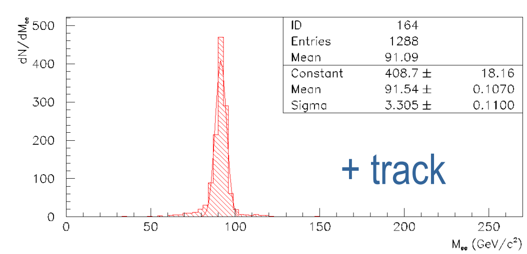
98% (99% per e)





10K Pythia Z→ee
<1.1>minBias
Preco04.00.01

98% (99% per e)



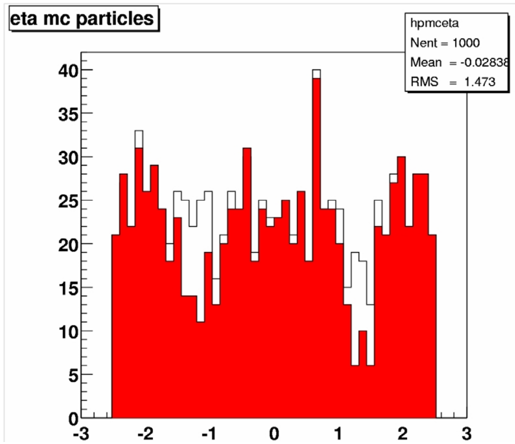
Soft Electron Finding

- Isolated electrons : EMReco

5 GeV single e

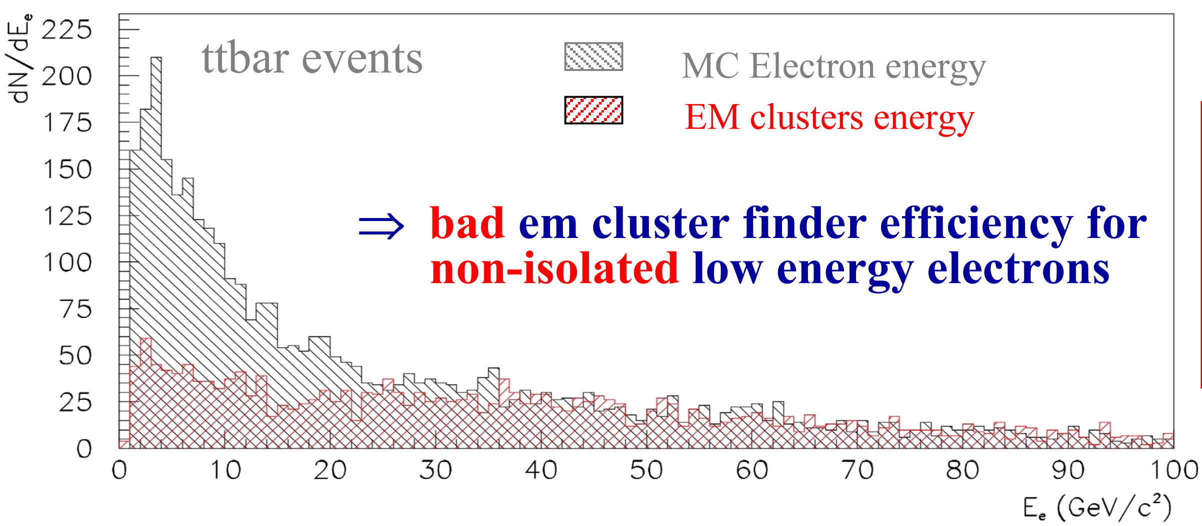
em clusters

(Serban's plot)



⇒ **good em cluster finder efficiency for isolated low energy electrons**

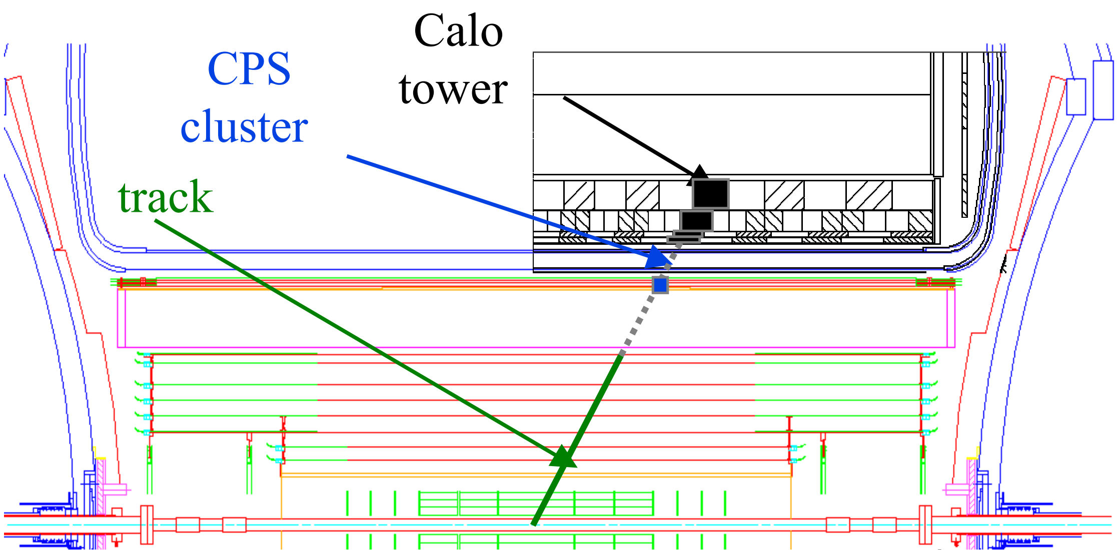
- Non-isolated electrons : EMreco



⇒ **bad em cluster finder efficiency for non-isolated low energy electrons**

SEMReco :
⇒ look at low E electrons near (in) jets
⇒ use tracks first !

Electron ID: non isolated electrons (low energy)

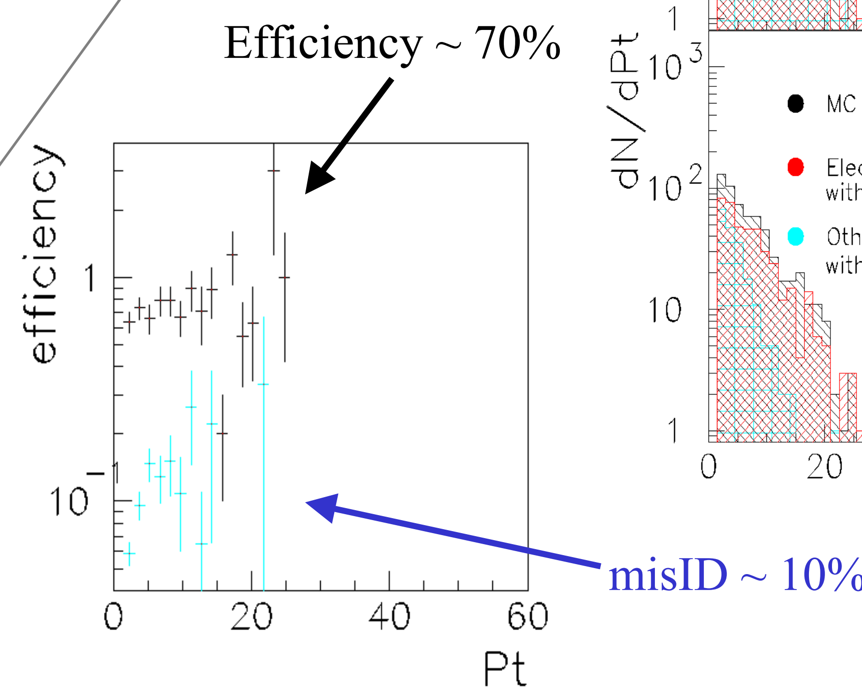


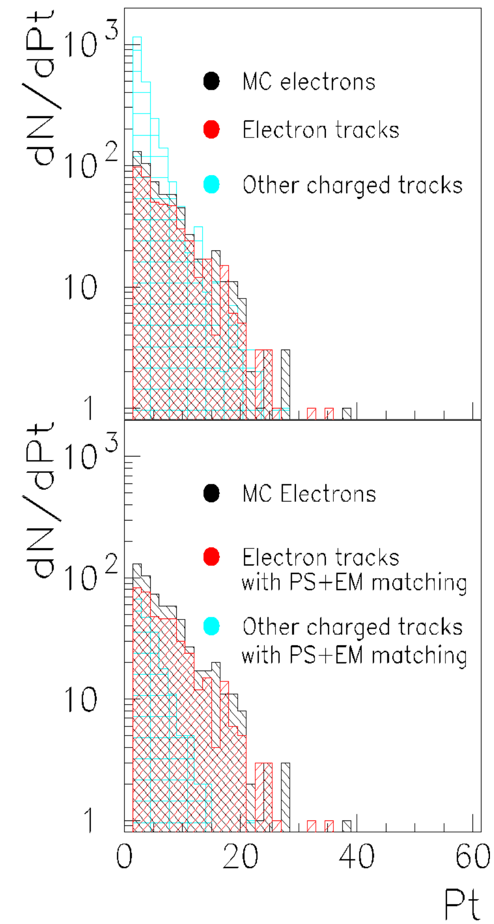
- New algorithm **developed at LBL**

- **an electron =** a track with:
  - a matching PS cluster
  - a matching Calo tower
    (+ EMfraction cut)

- *Still working on Bkg rejection using PreShower and Calorimeter granularity.*

Test on $Z \rightarrow b\bar{b}$ events



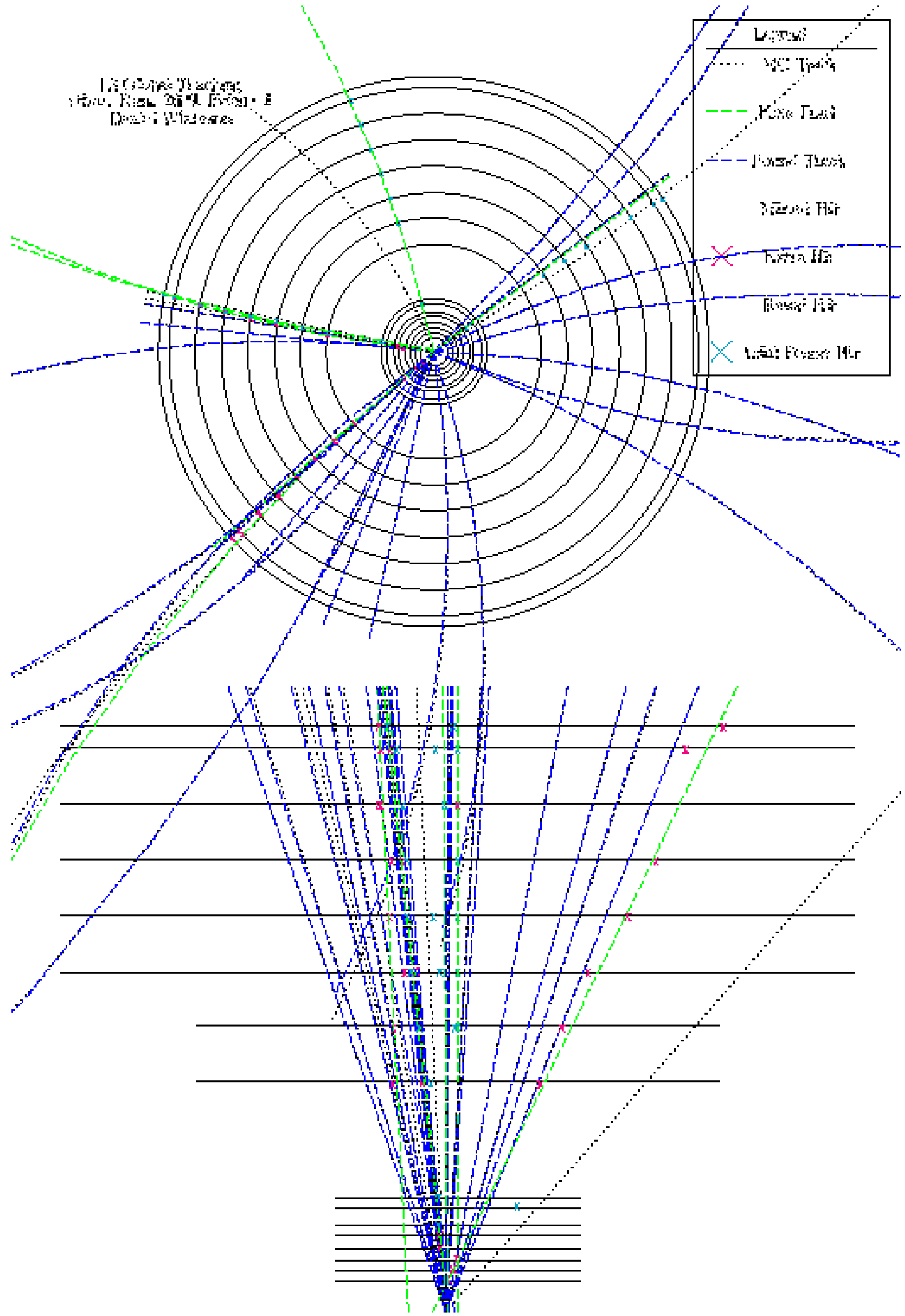


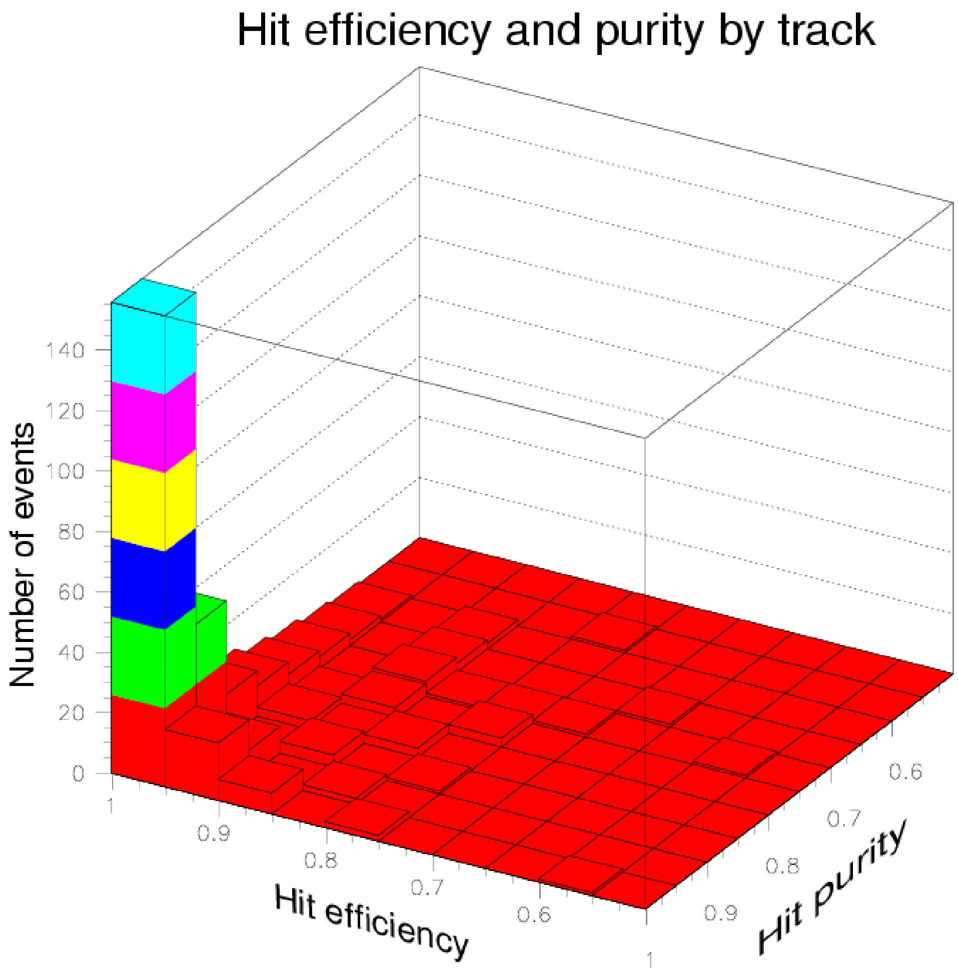
Ultrafast tracking for trigger

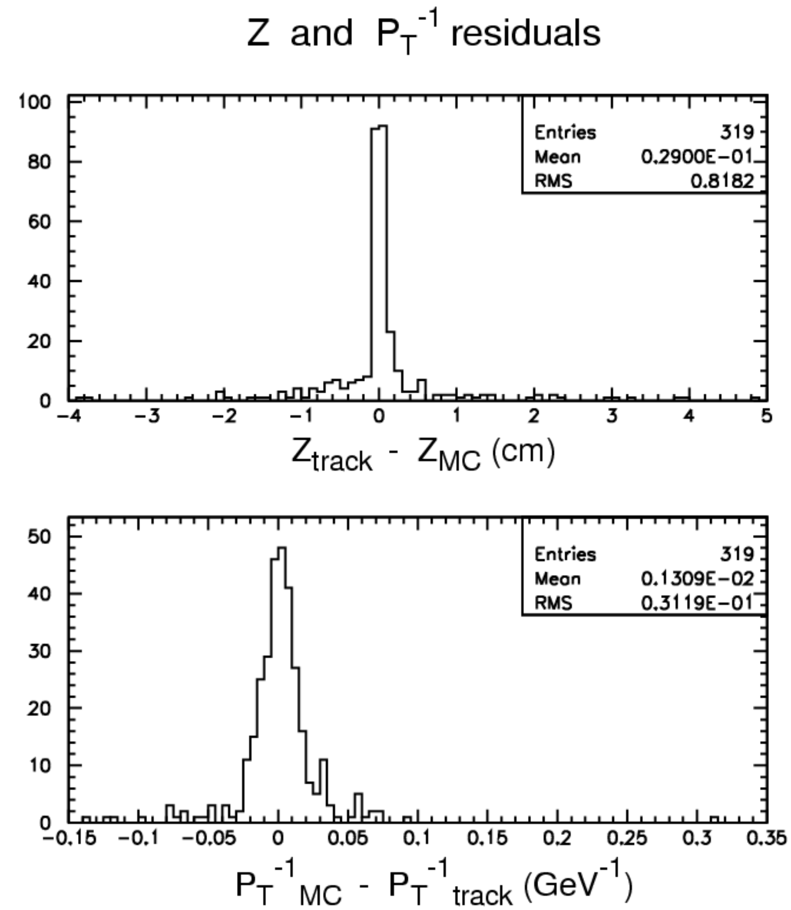
- Level 3 trigger is last stage
- Identify objects, e.g. leptons, photons
- Tracking is important in this ID
- Algorithm needs flexible P_T threshold for tradeoff between speed and efficiency at low P_T.

Level 3 tracking (2 stages)

- Axial Track Finding
  - Begins at outer Fiber Tracker
  - Extends inward thru 16 axial layers
- Stereo Track Finding
  - Small stereo angle: less accurate
  - Uses adaptive histogramming alg.
  - Zooms in on promising regions.

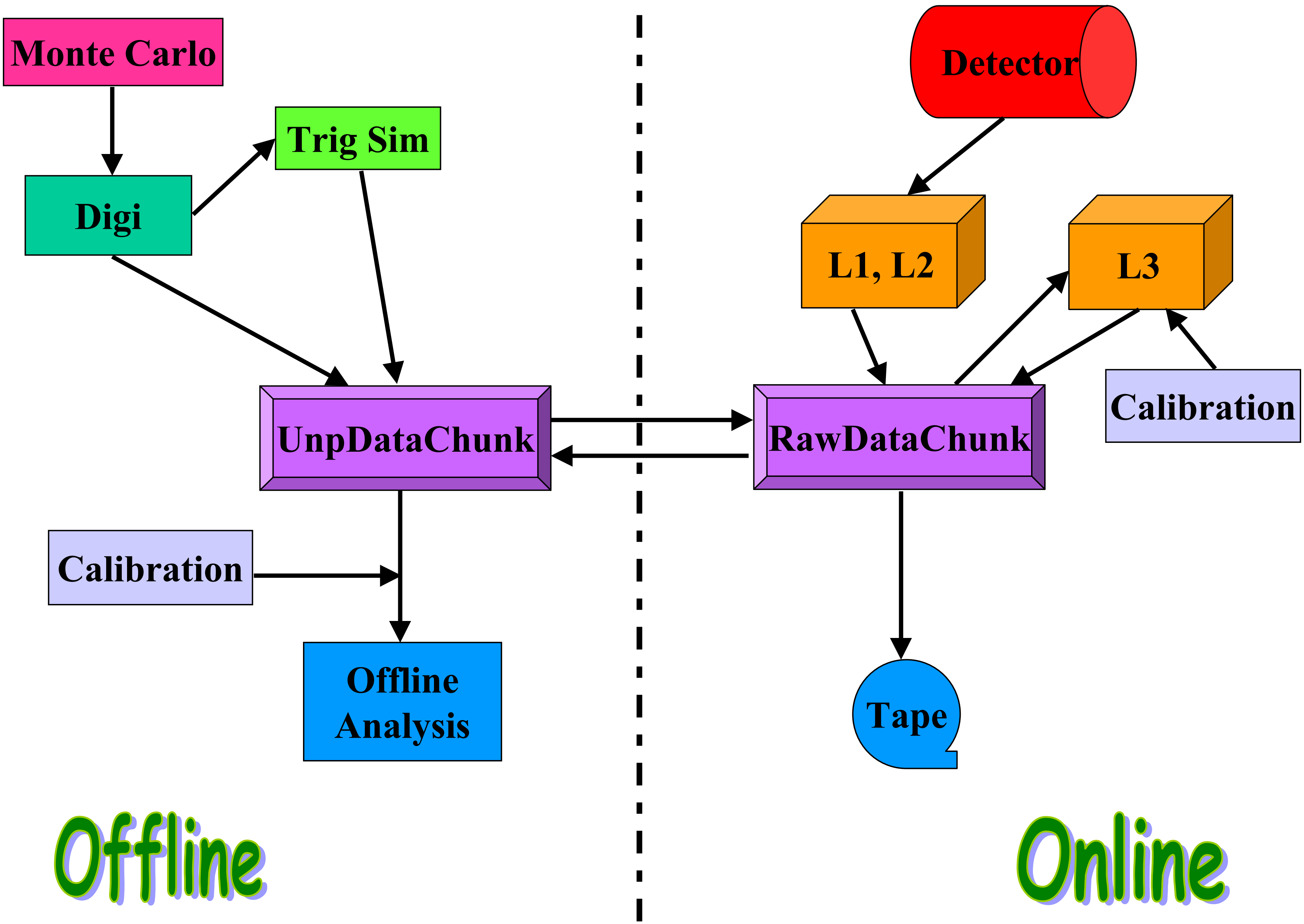


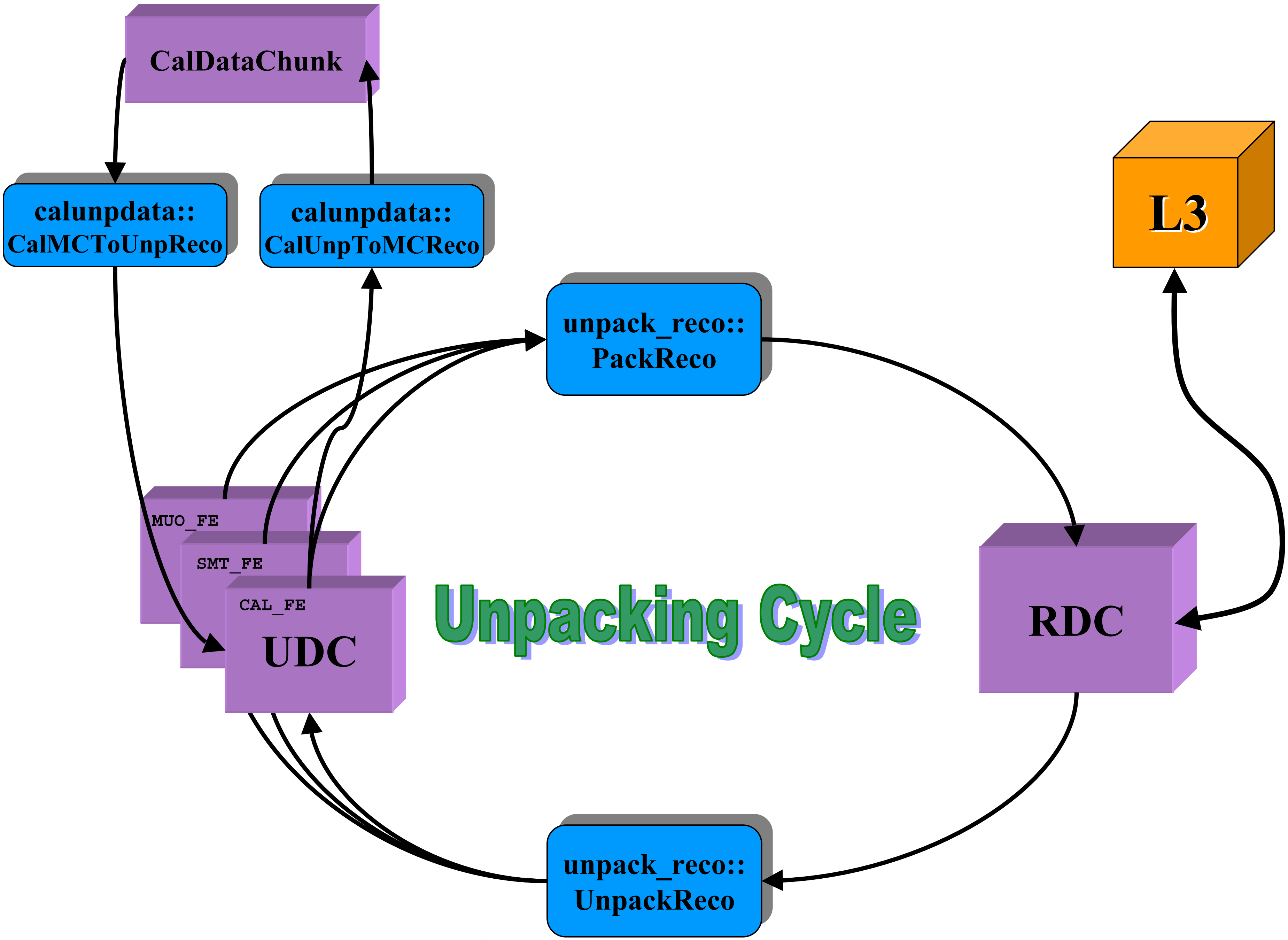

Hit efficiency and purity by track
Number of events
Hit efficiency
Hit purity
0
20
40
60
80
100
120
140
1
0.9
0.8
0.7
0.6


Z and P_T^{-1} residuals
Entries 319
Mean 0.2900E−01
RMS 0.8182
Z_{track} - Z_{MC} (cm)
Entries 319
Mean 0.1309E−02
RMS 0.3119E−01
$P_T^{-1}{}_{MC}$ - $P_T^{-1}{}_{track}$ (GeV^{-1})

Level 3 Trigger Software

- Run Configuration Management
  - describes readout electronics configuration
  - needed for online/offline packing/unpacking
- Trigger Name Translation Table
  - searchable wild-carded trigger name to trigger bits
- Raw Data Packing and Unpacking
  - MC data is digitized & packed into raw data for L3 testing
  - raw data is unpacked for offline analysis
- Calorimeter Software
  - implemented MC packing and raw data unpacking for Cal


Monte Carlo
Trig Sim
Digi
UnpDataChunk
Calibration
Offline Analysis
Detector
L1, L2
L3
RawDataChunk
Calibration
Tape
Offline
Online


CalDataChunk
calunpdata::
CalMCToUnpReco
calunpdata::
CalUnpToMCReco
L3
unpack_reco::
PackReco
MUO_FE
SMT_FE
CAL_FE
UDC
Unpacking Cycle
RDC
unpack_reco::
UnpackReco

The SVX2E Readout Chip

- Designed at LBNL and Fermilab. All post-foundry work is LBNL's responsibility. **Chips were tested here by physicists.**
- Delays, digitizes, sparsifies, and reads out 128 channels of data from DØ's Run 2 **silicon, scintillating fiber, central and forward preshower, and forward proton detectors.**
- The non-overlapping data acquisition and readout cycle is simple and well matched to the trigger bandwidth set by DØ's liquid argon calorimeter.
- All SVX2E chips from the original order of 120 wafers have been **ground, back-plated, tested, diced and packaged**. This order furnished **10,628 good chips** (60% yield).
- DØ realized in summer 1999 that **more chips would be needed** than expected, because an unexpectedly large number of Si readout circuit prototypes were built at Fermilab.
- In fall 1999, DØ purchased 35 additional wafers from UTMC. These wafers have been **processed, tested and packaged** to give **3,145 additional good chips** (61% yield).
- This supply of **13,773 good chips** have been distributed for production of detector components (the overall yield was 60%). It is **sufficient to complete the detector.**
- This effort is essentially complete.

Other recent D0 responsibilities and activities

- LBNL D0 Group (Madaras, leader)
- D0 Silicon Microstrip Tracker Software and Algorithms Group (Barberis, leader)
- Electron and Photon ID Algorithms Group (Madaras, coleader)
- Unpacking Coordinator (Leggett)
- Jets/Missing E_T Reconstruction/Trigger Review (Barberis)
- Tevatron Higgs Working Group (Barberis)
- Run 2 Thinkshop, strong interactions working group (Barberis, coconvener)
- Optimization of b-tagging algorithms for top and Higgs (Barberis, coconvener)
- Standing D0 Authorship Committee (Madaras, chair)
- D0 Authorship Rules Revision Committee (Barberis)
- D0 Advisory Council (Barberis)
- Shifts at silicon det, fab. facility, detector installation, DAQ (~100 days of shifts)

Recent D0 Editorial Board Participation

- Sleuth analysis (Madaras)
- Triple differential dijet cross section analysis (Barberis, chair)
- Direct search for a light charged Higgs boson (Barberis)
- Single top (Knuteson)
- Missing E_T reconstruction (Knuteson)
- $W \rightarrow \tau\nu$ analysis (Madaras, chair)
- End Cap W mass measurement (Madaras, chair)
- W mass using electrons near calorimeter module edges (Madaras, chair)
- Photon missing E_T jets (Trippe, chair)

Summary

- **LBNL D0 Group** was a **major participant** in D0 for **Run 1**:
  - Built **End Cap Electromagnetic Calorimeter** and **Vertex Detector**
  - Made major contributions to **physics analysis**, especially in **top quark physics, electroweak physics, jet energy scale,** and **new phenomena searches.**
  - First **Physics Coordinator** for all D0 analyses.
- Making **key contributions** to the D0 Upgrade for **Run 2:**
  - **Leaders** in Silicon Microstrip Tracker Algorithms and Electron ID
  - **Developers** of innovative analysis techniques: **Sleuth**
  - **Developers** of **SMT software**: geometry, calibration, tracking, graphics, alignment
  - **Developers** of **Level 3** tracking, trigger and run control
  - **Designers/testors** of **SVX2E** readout chip
- Will be key contributors to Run 2 physics.